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A Review of Aquatic Habitat Assessment Methods

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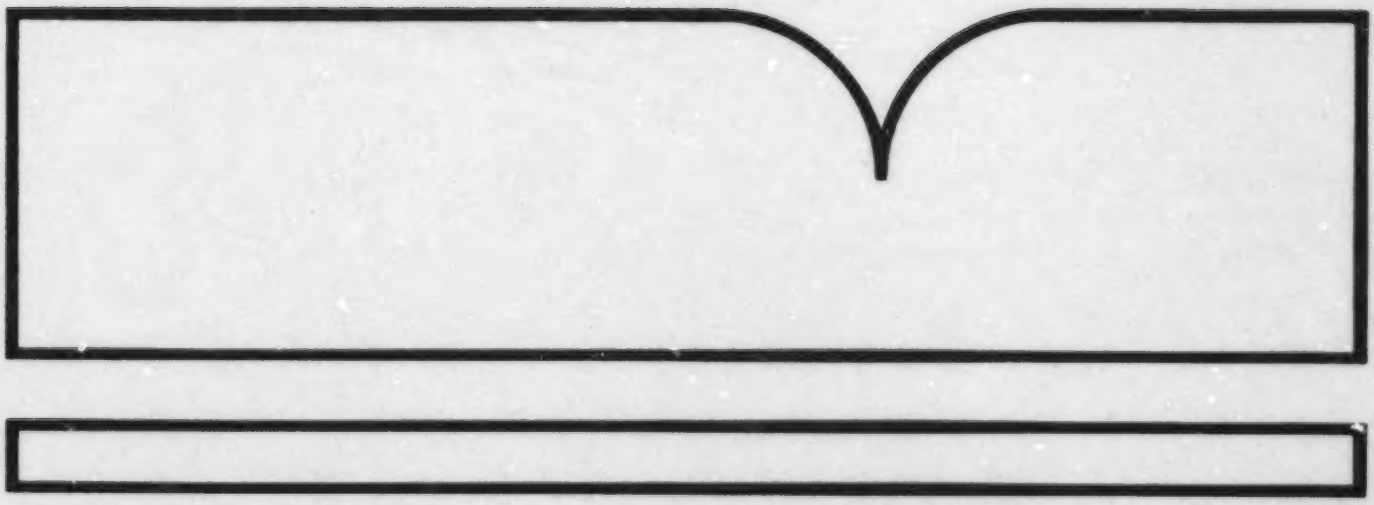

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A REVIEW OF AQUATIC HABITAT ASSESSMENT METHODS

by

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Approximately 30 aquatic habitat assessment techniques were summarized and compared to provide information to watershed and nonpoint pollution control managers. Most methods have been developed by Federal or state agencies and have had greatest application in the western United States. They are classified according to a number of mutually interacting categories such as impact assessment, inventory and general description, salmonid or non-salmonid streams, particular fish species orientation, channel stability, transect, and biotic indices. Many of the methods have developed indices or numerical values which can be used for comparisons or evaluation. Substantial effort is going into the development of habitat evaluation procedures (HEP) by the U.S. Fish and Wildlife Service, techniques designed for assessing project impacts oriented toward a particular species of interest. Parameters most frequently considered in the reviewed methods included flow, temperature, water surface width, turbidity, gradient, velocity, depth, bank stability measures, bottom size distribution, siltation, cover, pool size, attached begetation, fish and invertebrate types, riparian zone vegetation and shade, and obstructions such as waterfalls, dams, and culverts. While many methods are similarly based on such parameters as substrate, cover, flow, depth, and stream and floodplain morphology, the ultimate choice of metho depends on geographical location, stream type, investigator expertise, and project goals.

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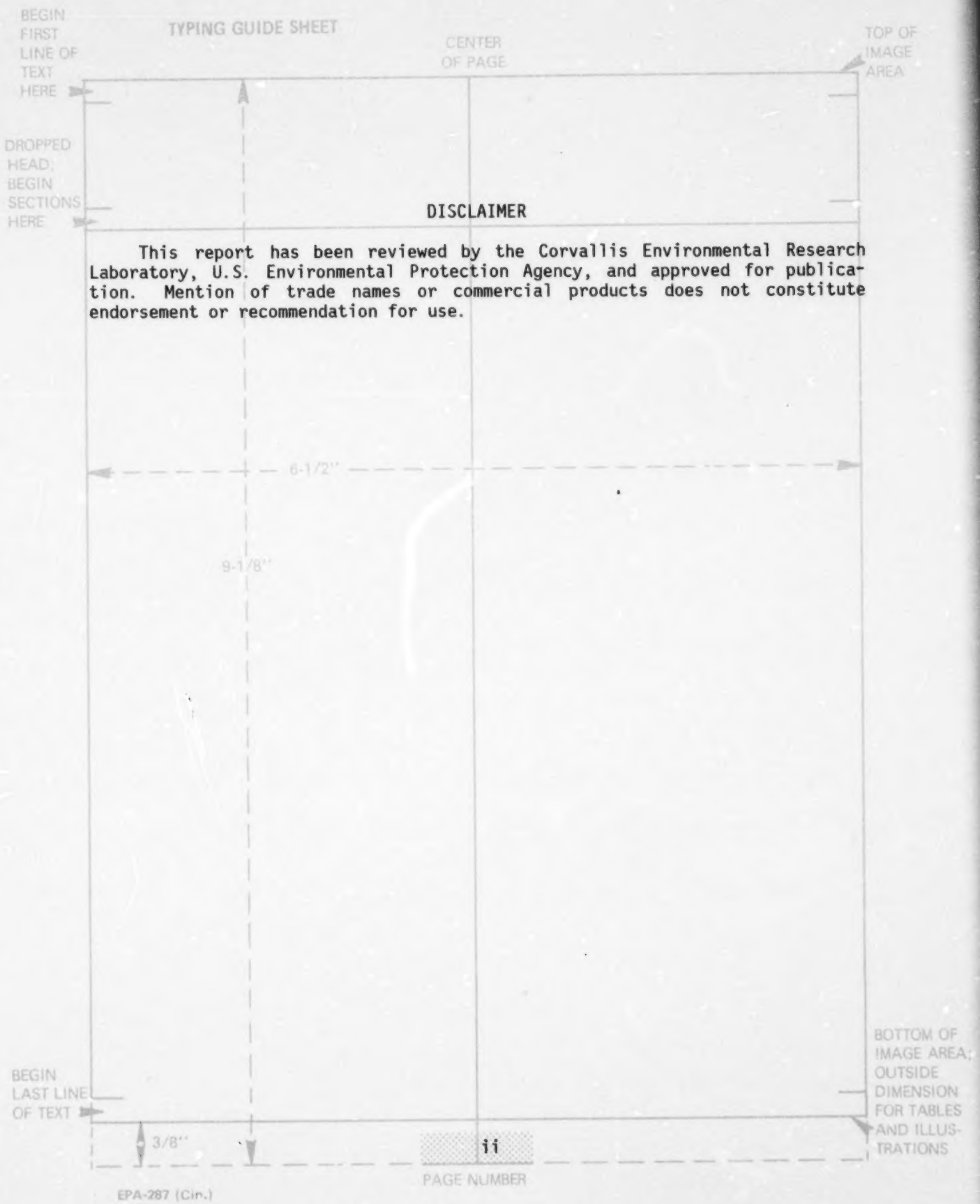

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ABSTRACT

Approximately 30 aquatic habitat assessment techniques were summarized and compared to provide information to watershed and nonpoint pollution control managers. Most methods have been developed by Federal or state agencies and have had greatest application in the western United States. They are classified according to a number of mutually interacting categories such as impact assessment, inventory and general description, salmonid or non-salmonid streams, particular fish species orientation, channel stability, transect, and biotic indices. Many of the methods have developed indices or numerical values which can be used for comparisons or evaluation. Substantial effort is going into the development of habitat evaluation procedures (HEP) by the U.S. Fish and Wildlife Service, techniques designed for assessing project impacts oriented toward a particular species of interest. Parameters most frequently considered in the reviewed methods included flow, temperature, water surface width, turbidity, gradient, velocity, depth, bank stability measures, bottom size distribution, siltation, cover, pool size, attached vegetation, fish and invertebrate types, riparian zone vegetation and shade, and obstructions such as waterfalls, dams, and culverts. While many methods are similarly based on such parameters as substrate, cover, flow, depth, and stream and floodplain morphology, the ultimate choice of methods for any purpose including nonpoint source pollution evaluation depends on geographical location, stream type, investigator expertise, economics, and precise project goals.

Work was initiated in December 1979 and completed in December 1981.

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The constructive comments of K. W. Malueg throughout this study and the efforts of many Federal and state researchers and administrators who supplied information and advice about habitat assessment techniques in their areas are gratefully acknowledged.

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SECTION 1

INTRODUCTION

Habitat assessment has long been recognized by natural resource agencies as an essential task in the management and preservation of fish and wildlife. The need by managers for detailed habitat inventory data for fish and other species to describe critical habitats for the benefit of these species has been aptly expressed by Jahn (1978). Water quality agencies are now beginning to realize that measuring the physical and chemical characteristics of the water column is insufficient to predict the biological condition of a stream system because of changes that can also occur in the quality of the physical environment from land use impacts.

Flow regime, water quality, habitat structure, and energy source are the most important variables affecting this biological integrity (Karr and Dudley, 1981). For instance, fluctuating water levels, storm events, available light, temperature, dissolved oxygen, suspended and dissolved materials, physical structure as reported by bottom type and channel configuration, and cover are all important interacting factors which influence the presence and distribution of invertebrates and fish. Activities such as urbanization, agriculture, silviculture, mining, construction, land disposal, and hydrologic modifications often have severe impacts upon physical habitat quality. Ischinger (1979) emphasized the importance of inventorying and identifying aquatic habitats in nonpoint source (NPS) management and characterized NPS pollution as the most pervasive and ubiquitous water quality problem in North America.

Habitat has been most simply defined as the place where an organism lives (Odum, 1971) or, in broader terms, as the relatively well defined places having sufficient resources of energy and matter providing necessary minimum life requirements (Davis, 1960). The relationships of habitat terminology concepts to natural resource management have been summarized by Coulombe (1978). The concept that habitat is crucial to organizing knowledge about wildlife so it can be used by forest managers (Thomas, 1979) can also be applied to the stream environment. Habitat is critical to organizing knowledge about aquatic life so it can be used by watershed managers.

Aquatic habitat assessment is closely related to the concept of stream classification. The parameters proposed in several classification schemes (Table 1) are those used in many habitat assessment techniques. Platts (1980) called attention to the lack of a workable system for classifying fish habitat and to the importance of developing such a system. Other studies have

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TABLE 1. HABITAT PARAMETERS IN SEVERAL STREAM CLASSIFICATION SCHEMES

Classification Scheme	Habitat Parameters	Remarks
Ricker, 1934	Width, depth, substrate, temperature, velocity, dissolved gasses and solids, plants, and animals	Ontario streams
Pennak, 1971, 1978	Width, flow, velocity, substrate temperature (summer and winter), turbidity, total dissolved inorganic and organic matter, hardness, dissolved oxygen, rooted aquatics, streamside vegetation	Broad applications in USA and world
Persoone, 1979	Width, slope, hardness, substrate, temperature	Western Europe

emphasized the importance of certain habitat parameters. For instance, Gorman and Karr (1978) correlated habitat complexity with fish species diversity using depth, bottom type and current. Depth, width, and elevation were found by Platts (1976) to be very important in controlling fish species density and composition.

There are few compilations of the diverse and scattered literature on aquatic habitat assessment. Hall and Knight (1981) reviewed the natural variability of stream salmonid populations with respect to models that quantitatively describe habitat quality. Wydoski and Duff (1978) compiled 390 references on stream habitat improvement, but included only a few on habitat assessment. A more complete effort by Harker et al. (1980) resulted in an excellent review and bibliography on the background and development of many assessment techniques, and included classification, information storage and retrieval, and inventory and evaluation procedures for both terrestrial and aquatic environments.

Approximately 30 methods, many interrelated, were located in a literature base formed in large measure by state and Federal agency reports. While these methods can generally be divided into categories based on stream type (salmonid or non-salmonid), purpose (impact assessment and general inventory), or technical approach, actual differences between many are slight. This

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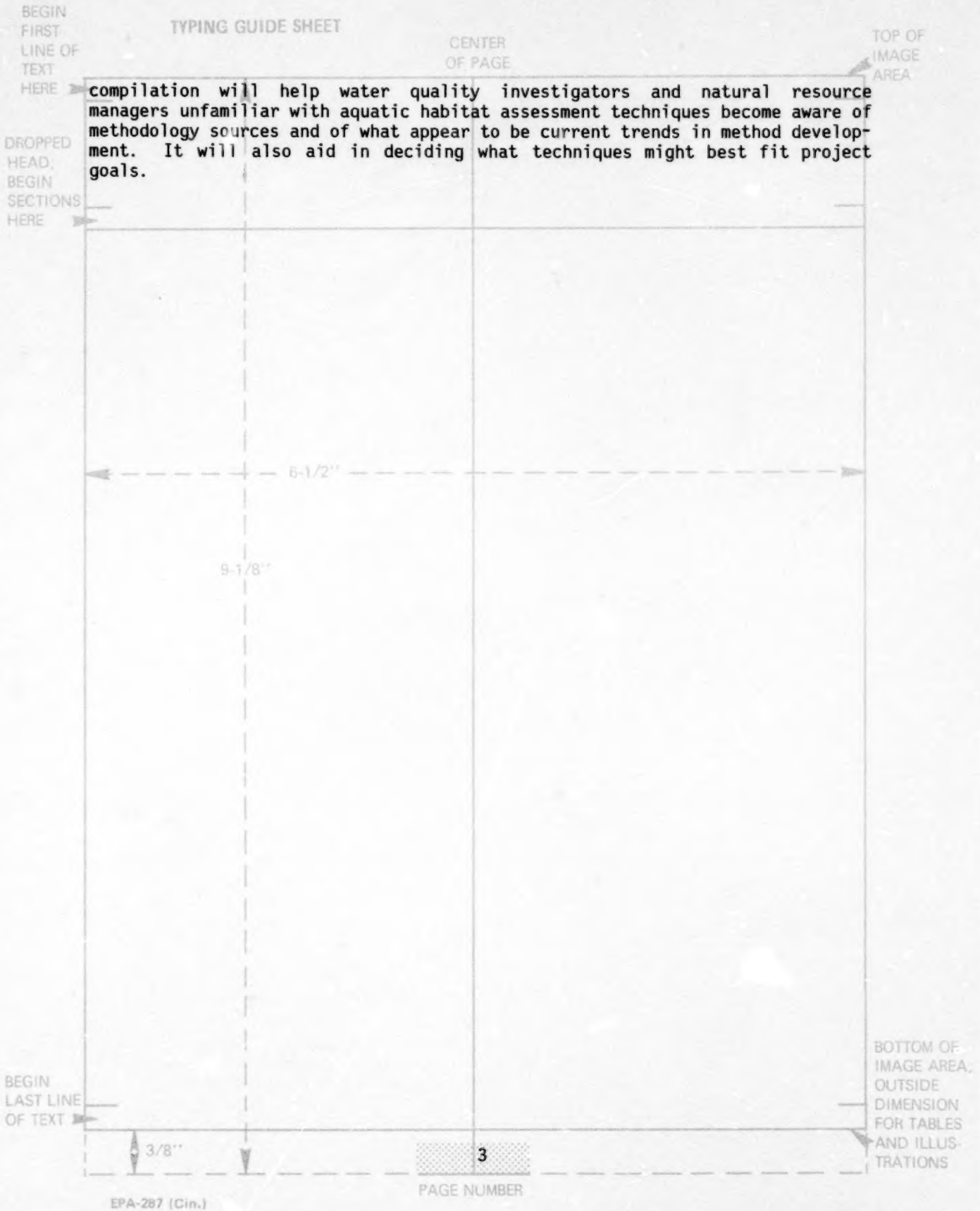
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compilation will help water quality investigators and natural resource managers unfamiliar with aquatic habitat assessment techniques become aware of methodology sources and of what appear to be current trends in method development. It will also aid in deciding what techniques might best fit project goals.
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SECTION 2

CONCLUSIONS

The development of habitat assessment procedures has progressed from simple surveys, many designed for inventory, and from simple index type rating systems to more complex, often species-oriented systems, frequently assisted by computerized information storage and retrieval. This increased development is a reflection of the recognition of the importance and usefulness of aquatic habitat in stream baseline and impact assessment. Many governmental agencies are presently developing techniques applicable to their own needs. The trend in method development is toward systems that recognize habitat potential as valuable. Comparing a stream's condition to its own potential is a large step forward in understanding perturbation effects. Much development is also going into techniques for mitigation determination.

A universal habitat assessment technique is probably not realistic because of the diversity of watershed and stream types, but a number of methods (Dunham and Collotzi, 1975; Collotzi and Dunham, 1977; Rickert et al., 1978; Stalnaker, 1978; Sternberg, 1978; USFWS, 1980b; O. Fajen, pers. comm.) have the potential, with regional adaptations, to be used over wide areas and should be considered when choosing a technique. The development of a technique applicable only to a certain type of pollutant or impact is also probably impractical, but the selection of a method which objectively measures the impact upon a stream parameter of interest can be useful. The development of methodology applicable to other than salmonid streams would be of great benefit to lowland watershed and resource managers.

Diverse interests and goals in different Federal and state agencies concerned with the enforcement of water quality standards, detection and documentation of pollution, protection of the natural environment, and management of natural resources has led naturally to the development of different types or views of habitat assessment techniques. Increased cooperation between agencies and increased awareness of new techniques can do much to promote the use and improvement of habitat technology. The ultimate choice of an aquatic habitat method, however, may hinge upon a complex of economics, available expertise, and project goals.

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SECTION 3

RECOMMENDATIONS

While the ultimate choice of a method depends on expertise, resources and project goals, methods which evaluate streams with regard to their own potential are more ecologically sound.

A most important requirement for any method is the need for field validation. It is only in this way that the ability of different methods to produce similar results can be determined. Individual methods need to be evaluated for reproducibility and range of test conditions.

Where resources are limited, a method based on visual stream analysis (Duff and Cooper, 1976, rev. 1978) may be the best choice.

Methods such as Rickert et al. (1978), Dunham and Collotzi (1975), and Eiserman et al. (1975), which evaluate physical structure in addition to other factors particularly related to fish spawning, residency, and migration should be considered when selecting a general purpose technique.

The Habitat Evaluation Procedures (USFWS, 1980b) should be considered for large projects where there is a concern for particular species.

Incremental flow methodology (Stalnaker, 1978, 1979a, 1979b) should be considered when habitat concerns are strongly linked to demonstrating the impact of flow regimes on fish habitat potential.

Supplemental methods such as those proposed by Crouse et al. (1981), Shirazi and Seim (1979), and Lotspeich and Everest (1981) should be considered when there is a particular interest in the relationships of salmonids and the stream bottom.

Most method development has been concerned with salmonid-type streams. Further development should concentrate on what criteria are necessary for non-salmonid stream assessment.

Cooperation should continue between concerned agencies and investigators to promote the improvement of assessment technology.

Measurement of physical habitat should not be an end in itself. In stream evaluation, habitat is but one variable among many which affect the biological integrity of a system.

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SECTION 4

METHOD CLASSIFICATION AND PARAMETERS

Many of the reviewed techniques are still under development, several are represented by a series of reports or publications and some are unpublished (Table 2). Federal agencies (U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, U.S. Soil Conservation Service) have been responsible for the majority of methods with state agencies (Department of Fish, Game, Conservation, Natural Resources, Wildlife) and interagency groups accounting for the remainder. Primary emphasis on method development has been in the West.

The methods can be classified into a variety of groups depending upon their intended purposes, stream types and technical approaches. These groups are not necessarily mutually exclusive, as a given method can be represented in several categories or be applicable to a number of situations. For instance, while most of the methods (25) appear to be used in salmonid streams, six are also used in non-salmonid waters but even these have been derived from salmonid type methods.

The methods can also be categorized according to purpose. Impact assessment techniques are used primarily to evaluate the impact of water and land resource development projects, construction and alterations due to human activity, differing flow regimes, and pollution. General description or inventory methods are primarily used for fisheries, water and land use planning and management, habitat research, baseline data inventories, and environmental statements.

Some of the salmonid stream methods are based in part on the U.S. Forest Service (USFS) Stream Reach Inventory and Channel Stability Evaluation. This methodology was developed by Pfankuch (1975) to systemize evaluations of the resistive capacity of mountain stream channels to bed and bank material detachment and to produce information on stream reaction to changes in flow or sediment production. Adding factors related specifically to aquatic organism habitat allows this approach to be used as a habitat assessment technique.

Target species or species-oriented type methods applicable to both salmonid and non-salmonid streams are designed for the assessment of habitat of a particular species or group of species. The approach is narrower and more species-oriented than other method types. It seems to have been used only by Federal agencies for impact assessment type evaluations. Some of the methods just described can also contain index and transect aspects. Index or numerical values facilitate comparisons or judgments between stations or locations, all major method groups contain some index producing techniques.

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TABLE 2. PRINCIPAL FEATURES OF HABITAT ASSESSMENT METHODS

Reference or Communication	Applicable Stream Type[1]	Location	Reported Use	Principal Feature and Comments
(1) Duff and Cooper, 1976, rev. 1978	S	Western States	General Inventory	Based on channel stability methodology (Pfankuch, 1975). Uses ocular survey techniques or more detailed transect sampling. Can be used on three levels of of effort. Ocular techniques can survey 1.6 km of stream in 1.5 hr.
(2) Duff, USBLM, Utah	S	Western States	General Inventory	Based on channel stability methodology. Data collected within .16 km segments at 1.6 km intervals. Methods not finalized. Survey costs $51/km, 1.4 km/person day.
(3) Rickert et al., 1978	S	Oregon	Impact Assessment	Based on modified channel stability methodology in addition to habitat factors of particular concern to salmonids. Developed in assessment of non-point stream erosion problems. Authors believe methods have wide use potential.
(4) Washington Dept. Ecology, Olympia	S	Washington	Impact Assessment	Uses Oregon's modification of channel stability methodology in addition to photographic technique. Also evaluates wildlife habitat in canopy and streamside zones. Emphasizes protection of streamside management zones.
(5) Coffin, 1979	S	Nevada	General Inventory	Based on channel stability methodology in addition to transect techniques of Dunham and Collotzi (1975).
(6) N. H. Newhouse, Kootenai National Forest, Montana	S	Montana	General Inventory	Based on channel stability methodology and habitat measurements. Uses point system to rank by parameters. Emphasizes resident and spawning fish habitat suitability.
(7) Cooper, 1979	S	Idaho, Wyoming	Impact Assessment	Based on channel stability methodology. Used primarily to predict grazing effects on stream banks and channels.
(8) Herrington and Dunham, 1967	S	Western States	General Inventory	Emphasizes features of pools, riffles, bottom composition, and riparian vegetation. Early development of transect sampling techniques.
(9) U.S. Forest Service, 1969	S	Montana, Idaho	General Inventory	Designed to evaluate conditions limiting fish production. An early version of Duff and Cooper (1976) without channel stability methodology.

Table 2. (continued)

Reference or Communication	Applicable Stream Type[1]	Location	Reported Use	Principal Feature and Comments
(10) Dunham and Collotzi, 1975	S	Western States	General Inventory	Enlargement of Herrington and Dunham (1967) emphasizing computer storage and data manipulation. Uses transect sampling and determines an index value of optimum habitat. Authors indicate that inclusion of additional variables may allow use in non-salmonid waters.
(11) Collotzi and Dunham, 1977, U.S. Forest Service, Ogden, Utah	S	Western States	General Inventory	Uses transect system of Dunham and Collotzi (1975) to form basis of General Aquatic Wildlife System (GAWS). Includes stream and lake analysis, habitat typing and component analysis, statistic and data inventory. Non-salmonid fish will eventually be included.
(12) Parsons, 1979	S	Oregon	General Inventory	Emphasizes spawning gravel, degree of flow retardation and stages of successional vegetation in riparian zone.
(13) Oregon State Game Commission et al., 1970	S	Oregon	General Inventory	Measures general physical and biological parameters in 0.4 km long survey units. A simple method still in limited use.
(14) Eiserman et al., 1975	S	Wyoming	Impact Assessment	Water chemistry and stream channel features are rated numerically. These scores are calculated into a habitat value of 1-10 with an accompanying adjective rating.
(15) U.S. Forest Service, Juneau, Alaska	S	Alaska	General Inventory and Impact Assessment	These techniques being tested in Alaska are based on five levels of intensity, three for inventory of resources and two for impact assessment. Data needs include fishery resource descriptions, physical and biological information, and baseline information on unmanipulated habitat.
(16) Binns, 1978; Binns and Eiserman, 1979	S	Wyoming	Impact Assessment	This is a complex system designed to quantify transect stream habitat with a Habitat Quality Index (HQI) predictive model. The model predicts standing crop, evaluates habitat in standard habitat units and compares habitat loss or gain.
(17) Nickelson and Hafele, 1978	S	Oregon	General Inventory	Regression models describe relationships between stream habitat and infaunal rearing potential at low flows and predicts amount of habitat at any flow. Stresses need for testing.

Table 2. (continued)

Reference or Communication	Applicable Stream Type[1]	Location	Reported Use	Principal Feature and Comments
(18) Riparian Habitat Subcommittee, 1979	S	Washington, Idaho	General Inventory	An interagency effort to evaluate riparian ecosystems. Percentage of evaluated features are compared to optimum habitat conditions. Recommend optimum features.
(19) Greentree and Aldrich, 1976	S	California	General Inventory	This unconventional approach to trout habitat assessment uses aerial photography. Authors report high degree of correlation with actual conditions, can assess about 25 km/person day.
(20) Seehorn, 1970	S, NS	Georgia, Virginia, So. Carolina	General Inventory	Designed to evaluate trout waters but appears applicable to headwater bass streams. An index value is given for both present and potential conditions.
(21) U.S. Soil Conservation Service, 1977	S, NS	--	Impact Assessment	Develops guidelines for protection of stream habitat by scoring various factors. These scores are modified by an importance factor and converted to a final grade of 1-10. A use rating is also determined primarily designed for channel projects.
(22) O. Fajen, Missouri Dept. Conservation, Columbia	S, NS	Missouri	Project Assessment	This method, still under development, rates various stream factors on a scale of 1-10. Evaluated factors are intended to be free from subjective judgment.
(23) Sternberg, 1978	S, NS	Minnesota	General Inventory	Designed to determine the best fishery management procedures. Surveys are in two phases: 1) surveying the entire stream, and 2) collecting detailed information on flow, watershed, physical/ chemical, and biological factors
(24) Stalnaker, 1978, 1979a, 1979b	S, NS	Widespread	Impact Assessment	Designed to demonstrate the impact of any given flow regime on fish habitat potential. Uses computer simulation and increased flow methodology. Sampling done in transects. Method oriented to a particular species of interest.

Table 2. (continued)

Reference or Communication	Applicable Stream Type[1]	Location	Reported Use	Principal Feature and Comments
(25) U.S. Fish & Wildlife Service, 1976; Raleigh, 1978; USFWS, 1980a; Western Energy Land Use Team, Ft. Collins, Colorado	S, NS	Widespread	Impact Assessment	Methods represent Habitat Evaluation Procedure (HEP) which results in a quantitative index value for assessing habitat. Early methods, still in use, are based on a score developed from capacity of habitat to meet requirements of 10 representative species. Later developments include use of a habitat suitability index where selected parameters are measured and compared with habitat requirements as indicated by response curves. A very sophisiticated system requiring high degree of expertise, most valuable for larger projects.
(26) U.S. Soil Conservation Service, 1978	NS	Kansas	Impact Assessment	Rates physical, chemical, and biological habitat attributes on a score of 1-10. These values are used to compute an average habitat value which can be converted into habitat units.
(27) Kansas Fish and Game Commission	NS	Kansas	Impact Assessment	Designed to evaluate Kansas bridge projects. Rates chemical and biological features on scores of 1-5 or 1-10 which are combined to obtain total habitat score. Undergoing revision. An example of an inexpensive procedure.

[1] S = Salmonid, N = Non-Salmonid.

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Transect methods are based upon sampling a transect across the stream in contrast to a stream reach of particular length. Only Federal agencies seem to have emphasized this type of approach.

The major habitat parameters and related factors used or evaluated in the various methods are grouped in Table 3. The groups (surrounding area, riparian zone, general descriptors, stream banks, stream bottom, fish habitat, limiting factors, and biology) are each presented with a percentage indicating the relative number of reviewed methods using the parameters within a group. Individual parameters are ranked and listed according to predominance of use.

Habitat parameters associated with surrounding stream areas are characterized by topographical and geographical features and land use of the surrounding and upstream areas. A more closely associated area, the riparian zone, gives primary importance to vegetative type, shading effect, and streamside cover. Most of the methods used a large variety of descriptive terms to characterize habitat. Some of the more important include flow, temperature, width, velocity, gradient, turbidity, and depth.

Stream banks are considered important. The parameters here are mostly those used in the USFS channel stability methodology. Bank stability, a related term, is preferred in non-channel stablity oriented methods. Substrate size distribution is an important stream bottom parameter.

Many of the methods stress various aspects of fish habitat, with instream cover and the number and size of pools ranking highest. Obstructions to fish migration, are primarily characterized by culverts, dams, and debris piles. Non-physical factors associated with habitat analysis include features such as attached algae and macrophytes, fish species, size, weight, and abundance.

Many of the methods were designed using English measurements. These units were converted into the metric (SI) system where practicable; an equivalent was added in parentheses when a conversion might change an author's intent.

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Table 3. Habitat parameters and related factors used or evaluated in various types of assessment methods.

Habitat Parameters	Salmonid-Type Streams																			Salmonid/Non-Salmonid Type Streams						Non-Salmonid Type Streams	
	1. Duff and Copper 1976, rev. 1978	2. Duff, USBLM	3. Rickert et al. 1978	4. Washington Dept. Ecology	5. Coffin 1979	6. Newhouse, Kootenai Nat. For., Montana	7. Cooper 1979	8. Oregon State Game Comm. et al. 1970	9. Herrington and Dunham 1967	10. U.S. Forest Ser. 1969	11. Dunham and Collotzi 1975	12. Collotzi and Dunham 1977	13. Parsons 1979	14. U.S. Forest Service, Juneau, Alaska	15. Eiserman et al. 1975	16. Binns 1978, Binns and Eiserman 1979	17. Riparian Habitat Subcom. 1979	18. Nickelson and Hafele 1978	19. Greentree and Aldrich 1976	20. Seehorn 1970	21. U.S. Soil Cons. Ser. 1977	22. Fajen, Missouri Dept. Cons.	23. Sternberg 1978	24. Stalnaker 1978, 1979a, 1979b	25. USFWS 1976, 1980a Raleigh 1978[1]	26. U.S. Soil Cons. Ser. 1978	27. Kansas Fish and Game Comm.
Surrounding Area (36%)[2]																											
surrounding land use			X	X							X			X								X				
topography/geography	X	X			X						X	X															
upstream land use			X	X																							
historical land use														X													
flood plain condition																							X				
urbanization																							X				
Riparian Zone (78%)[2]																											
vegetation species/type	X	X	X	X	X				X				X	X					X	X	X						
percent shade	X	X	X		X						X		X				X		X	X				X			
streamside cover	X		X		X					X				X					X				X	X			
vegetation size			X	X											X	X			X								
vegetation density			X												X	X						X					
width of zone		X				X							X														
ungulate grazing/damage	X				X		X																				
flood plain width									X																		
vegetation successional stage													X														
General Descriptors (100%)[2]																											
flow	X	X		X	X	X	X	X			X	X	X	X	X	X	X			X	X		X			X	X
water temperature	X	X	X	X	X	X	X	X		X	X		X	X	X	X				X	X		X	X	X		
water surface width	X	X	X	X	X				X	X	X	X	X	X	X	X				X	X		X	X		X	
color/turbidity/transparancy	X	X	X	X	X	X	X	X		X				X	X	X			X	X	X		X				
gradient	X	X	X	X	X	X	X		X	X	X	X	X	X									X		X		X
velocity	X	X	X	X	X	X	X			X	X	X	X		X	X		X	X	X				X			
average depth	X	X	X	X	X			X	X	X	X			X	X	X				X			X				
air temperature	X	X	X	X	X	X	X	X		X	X		X	X						X			X				
channel width	X	X		X	X	X	X			X	X	X	X		X												
length of segment	X	X	X								X		X						X	X		X					
elevation	X	X			X				X	X	X				X					X							

(continued)

Table 3 (continued)

Habitat Parameters	Salmonid-Type Streams																		Salmonid/Non-Salmonid Type Streams						Non-Salmonid Type Streams	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25[1]	26	27
pool/riffle ratio	X		X		X							X		X		X				X	X				X		
stream order	X	X	X	X	X	X	X			X					X												
stage/level	X	X								X				X	X	X				X			X				
stream length	X				X			X	X	X					X								X				
channel type/configuration			X	X															X	X						X	
tributaries/tributary of		X										X	X								X		X				
sinuosity	X	X				X	X																X				
pollution sources																				X		X	X			X	X
bottom composition--general			X			X	X																X				
valley bottom width					X					X					X						X						
valley type/configuration										X	X	X															
weather			X		X															X							
drainage area	X														X												
watershed type															X						X						
water source(s)																											
water use																											
percent channelized																X											
stream area																											
direction of flow		X																									
Stream Banks (57%)[2]																											
bank stability	X				X			X	X	X	X				X			X									
landform slope	X	X	X	X	X	X	X								X												
mass wasting	X	X	X	X	X	X	X								X												
debris jam potential	X	X	X	X	X	X	X																				
vegetative bank protection	X	X	X	X	X	X	X																				
channel capacity	X	X	X	X	X	X	X																				
bank rock content	X	X	X	X	X	X	X																				
obstructions	X	X	X	X	X	X	X																				
cutting	X	X	X	X	X	X	X																				
deposition	X	X	X	X	X	X	X																				
percent erosion/bare soil		X													X	X				X			X				
height banks															X								X				
percent damage		X																									
percent grazing																							X				
Stream Bottom (86%)[2]																											
bottom size distribution	X	X	X	X	X	X	X	X	X	X	X	X			X	X			X	X					X		
siltation/sedimentation	X	X	X	X	X									X				X		X	X			X		X	X
consolidation/ particle packing	X	X	X	X	X	X	X								X												
rock angularity	X	X	X	X	X	X	X								X												
brightness	X	X	X	X	X	X	X																				
scouring/deposition	X	X	X	X	X	X	X																				
imbeddedness					X						X																

(continued)

Table 3 (continued)

Habitat Parameters	Salmonid-Type Streams																		Salmonid/Non-Salmonid Type Streams						Non-Salmonid Type Streams	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25[1]	26	27
percent channel movement		X																									
roughness coefficient												X															
Fish Habitat (75%)[2]																											
instream cover			X	X	X	X				X	X	X		X		X	X						X	X	X		
pool length/width	X				X	X		X	X			X				X							X				
pools no./percent	X	X			X	X										X				X							
riffle width								X	X	X	X				X	X											
spawning gravel abundance/volume		X			X	X						X	X		X												
pool depth				X						X	X	X	X														
pool area		X										X	X														
spawning gravel quality		X										X	X														
riffle depth				X								X				X											
riffles percent																X				X							
spawning gravel size						X						X															
runs percent																X				X							
nursery habitat																					X						
riffle velocity																X											
runs width																X											
runs depth																X											
runs velocity																X											
Biology (86%)[2]																											
attached algae/macrophytes	X	X	X	X	X	X			X	X	X				X				X	X			X				
fish species	X	X	X							X		X		X	X	X		X		X	X		X		X	X	X
invertebrate type/species	X	X								X		X								X	X		X			X	X
invertebrate abundance/rank	X	X								X		X				X				X			X				
fish abundance	X	X	X									X					X			X			X	X			
fish size/weight	X	X	X									X								X			X				
invertebrate diversity	X	X								X						X				X			X				
Obstructions (43%)[2]																											
culverts		X								X	X	X						X								X	
beaver dams/dams		X																X				X	X			X	
waterfalls		X										X						X		X						X	
debris piles/slides			X									X			X				X	X							
log jams		X										X						X									
channelization																							X			X	
dredging																							X			X	
impoundments																					X						
levies/dikes																										X	
riprap																										X	

[1] Reference 25. Early HEP methodology (Form 3-1101) assessed habitat according to its worth for fish. Parameters used in later HEP Methodology can vary depending upon species of interest. Example here is from draft cutthroat trout guidelines.

[2] Maximum percent of methods using parameters in each habitat parameter group.

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SECTION 5

ASSESSMENT TECHNIQUES

SALMONID STREAM METHODS

Channel Stability Group

Channel stability methods, those based in large part on USFS Stream Reach Inventory Techniques (Pfankuch, 1975), are designed for cold water western streams. This basic technique evaluates 15 physical parameters on a numerical scale in major stream divisions of upper banks, lower banks, and bottom. Total scores are then expressed as poor, fair, good, or excellent. In aquatic habitat analysis, factors relating specifically to fish habitat are added to supplement the physical factors. Two stream bottom parameters, rock angularity and brightness (Table 3), were considered by Sachet (1977) to be inadequate estimators of bedload movement in areas of volcanic or sedimentary bedrock. The original parameters were developed for granitic rock where angular fragments with a high reflectance indicate polishing and crumbling caused by movement of bottom materials.

Duff and Cooper (1976, rev. 1978) designed a technique usable on three levels depending upon objectives and priorities. Level 3, a minimum survey, is based upon obtaining background data and conducting an ocular or primarily observational survey upon representative reaches. Level 2, an extensive field survey, includes Level 3 analyses and adds transect sampling. Level 1, an intensive field survey, includes the first two levels, the collection of sufficient data for an 80% confidence level, fish and benthic fauna measurements, and permanent transect marking.

The transect analysis basically involves establishing stream stations at 1 mile (1.6 km) intervals. Five transects are then established at 100 ft. (30.5 km) intervals upstream from each station. Measurements across each transect include a variety of parameters (Table 3). The data are analyzed with regard to factors considered absolutely essential for maximum fish production and more easily improved with stream management projects. A percent of optimum habitat is also calculated. The ocular survey technique, Level 3, is considered to be a quick alternative to transect sampling as 1 mile (1.6 km) of stream can be surveyed in 1.5 hr. The evaluated parameters are not as extensive or detailed as those in the transect survey, but do include the USFS stability analyses (Pfankuch, 1975).

D. Duff (Utah State Office, USBLM, Salt Lake City, pers. comm.) proposed methods designed to provide a standard analytical procedure for habitat assessment. Site specific data (Table 3) were collected within 0.1 mile (.16 km) long segments established at 1 (1.6 km) intervals. Procedures for estimating costs and manpower are also included.

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Rickert et al. (1978) in an assessment of erosion problems modified Pfankuch's (1975) technique by using three categories of stable, moderately stable, and unstable for Oregon mountain and lowland streams. Habitat factors of specific concern to salmonids are also evaluated and include spawning area conditions, bottom rearing area conditions, and barriers to upstream fish passage. Two major objectives of this methodology are the formation of a procedure that can be used throughout the country and the development of technically sound information describing the effects of land management activities.

The Washington Department of Ecology (D. Hobbs, pers. comm.) uses Oregon's techniques (Rickert et al., 1978) in addition to supplemental fish and wildlife data to evaluate aquatic habitats in western streamside management zones. A management zone is defined as an area, varying from 25 (7.6 m) to 50 (15.2 m) feet wide, adjacent to natural waters where specific attention must be given to water quality protection measures. A wildlife habitat rating for birds, animals, and amphibians in canopy, subcanopy, ground, stream edge, and stream channel areas are used in addition to the aquatic features tabulated in Table 3. The evaluation of each zone also includes a series of three photographs.

Nevada stream inventories combine two methods (Coffin, 1979). Habitat inventory analysis is by the transect method of Dunham and Collotzi (1975), reviewed in another section, while stream and channel stability is evaluated using the method of Pfankuch (1975). The data are coded for later storage, retrieval and manipulation.

H. Newhouse (Kootenai National Forest, Libby, Montana, pers. comm.) developed a habitat assessment technique to objectively stratify habitat from a suitability standpoint. Pool habitat, instream cover, stream side cover, food abundance, and channel stability are considered key parameters in assessing resident fish habitat suitability. Instream cover, channel stability, and species habitat are the key parameters for assessing spawning habitat suitability. Each parameter is subdivided into levels, each with a point value. The sum of these values results in one of five ranks ranging from unsuitable to very high suitability.

Cooper (1979) described a technique to evaluate and predict ungulate grazing effects on stream banks and channel stability in some northern Idaho and Wyoming streams. Mass wasting, bank vegetation, bank rock content, and bank cutting provide good measures of damage. Such grazing damage can reduce streamside cover and increase the release of smothering sediment.

Transect Group

The U.S. Forest Service (1969) developed an early version of the transect method of Duff and Cooper (1976), already mentioned, but without the channel stability techniques of Pfankuch (1975). While it includes a listing of warm water fish of the area, emphasis is primarily on salmonid habitat requirements.

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Another early step in the development of transect sample techniques for western streams is represented by Herrington and Dunham (1967). Measurements (Table 3) are taken at five transects established at each sample point at right angles to stream flow. Dunham and Collotzi (1975) enlarged upon this technique and recorded habitat features in a manner designed for easy computer storage and later recall and manipulation. This latter version also includes a procedure to determine a habitat percent of optimum value. The authors indicated that while the transect methods as applied were biased toward cold water species, the possible inclusion of additional variables would make them usable in warm water habitats.

A computerized wildlife management information system now undergoing updating and revision will soon be included in a Regional Aquatic Handbook by the U.S. Forest Service (Collotzi and Dunham, 1978; D. Dunham, U.S. Forest Service, Intermountain region, Ogden, Utah, pers. comm.). Known as the General Aquatic Wildlife System (GAWS), the system includes elements of stream analysis, lake and reservoir analysis, macroinvertebrate analysis, stratification criteria, and data management programs. Habitat typings and ratings, habitat component analysis, statistical measures, data inventory, and summation programs can be provided by the computer to provide a basis for assessments of present conditions and planning. The field inventory procedure is essentially the transect technique of Dunham and Collotzi (1975). Warm water fish lists have been included in the proposed system as a first step in the eventual adaptation to both warm and cold water streams.

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An extensive field survey technique was designed to provide a basic inventory for land and resource management planning in the Siuslaw National Forest in Oregon (Parsons, 1979). Sampling is conducted in sections defined as transects, but unlike a line across the stream, these transects are 100 ft. (30.5 m) sections of stream which extend 50 ft. (15.2 m) upstream and 50 ft. downstream from midpoints set at 0.5 mile (0.8 km) intervals. This method emphasizes a different approach to usual inventory techniques in several of these categories. Special attention is given to evaluating the quality of salmonid spawning gravel. A roughness coefficient, "N", is used to estimate the degree of flow retardation due to banks, bottom, and obstructions. Six stages of successional vegetation in the riparian zone are recognized. Barriers to fish passage are examined in detail and special data forms are used for cases of logjams, landslide, culverts, and falls.

Diverse Method Group

Several methods which do not fit readily into the other categories in this section demonstrate a wide range of complexity and purpose. The first, a simple general inventory method, still in limited use, was developed about 10 years ago by four cooperating state and Federal agencies (Oregon State Game Commission et al., 1970). It recommends that survey units be 0.25 miles (0.4 km) long and emphasizes the inventory of width, turbidity, extent of gravel and pools, cover, fish species and abundance, and limiting factors.

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Guidelines for the inventory and evaluation of cold water Wyoming streams with flows < 5000 cfs (508,000 m^3/hr) were developed by Eiserman et al. (1975). Their method for impact assessment also includes rating systems for terrestrial habitat, aesthetics and recreation. Sampling location is based on the division of the stream into reaches of different habitat diversity. Water chemistry features and stream channel features are rated from 1 to 10. These scores are converted into a habitat value from 1 to 10 which has an accompanying rating of poor, fair, good, or excellent. Low scores indicate a limiting feature which then may possibly be improved.

The first three levels of a multi-level technique being tested by the U.S. Forest Service (W. Sheridan, Juneau, pers. comm.) in Alaska are designed for inventory purposes. The first level is designed to provide only the most general description of fishery resources through an office-based technique. The second level is an inventory of known physical and biological information with placement of the information in a central file for later use. The third level is a field survey designed to provide baseline information on unmanipulated habitat. Needs for quantitative data are minimal while qualitative needs are at a maximum.

The remaining two levels are designed for impact assessment. Level four is a basic survey intended where a non-natural alteration of fish habitat has been predicted. Needs for qualitative data are minimal, while quantitative needs are at a maximum. This level is intended for an area programmed for major land use activities. The fifth or final level, an implementation survey, is the most intensive and is to provide information needed to coordinate final site-specific needs for resource uses.

Predictive Model Group

Binns and Eiserman (1979) developed a system to quantify Wyoming trout stream habitat in response to the need for non-monetary evaluation of fishery resources. Multiple regression analyses of various habitat parameters and trout standing crop resulted in the formation of a Habitat Quality Index (HQI) predictive model. Attributes having the closest relationship to trout standing crop were late summer stream flows, annual stream flow variation, water velocity, cover, stream width, eroding stream banks, stream substrate, nitrate, and maximum summer stream temperature. These are rated into five categories from 0 (worst) to 4 (best). The model explained 96% of the variation in trout standing crop ($R = 0.983$), suggesting a close relationship between trout stocks and HQI predictions.

Potential uses of the HQI method include a prediction of trout standing crop, an evaluation of trout habitat in terms of standard habitat units (HU = the amount of habitat quality required to produce an increase of 1 kg/ha in trout standing crop) and a comparison of habitat loss or gain at proposed project sites (Binns, 1978).

Nickelson and Hafele (1978) are developing regression models in Oregon to describe the relationship between stream habitat and salmonid rearing potential during low flow and to predict the amount of habitat at any given flow.

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Two cutthroat trout models explained 87-91% of the variation in standing crop and are based on transect-measured depth, velocity, cover, and substrate. The models are based on a Habitat Quality Rating (HQR_{ct}) derived from the product of a cover value, a velocity preference factor, and the wetted area of the section. The steelhead trout model is based upon a Habitat Quality Rating (HQR_{st}) derived from the product of a cover value, a depth and velocity value, and a value for the wetted area. The authors stressed the need for testing the models.

Riparian Zone Group

An interagency effort outlined a procedure to evaluate riparian ecosystems and to establish recommendations for managing fish and wildlife (Rip. Hab. Subcomm. 1979). Shaded stream surface, stream bank stability, and streambed sedimentation are used to evaluate fish habitat and other parameters related to wildlife. Optimum features are: 1) between 60 to 100% of the stream should be shaded from June to September from 10 a.m. to 4 p.m., 2) 80% or more of the total lineal bank distance should be in a stable condition, and 3) no more than 15% of the streambed should be covered by inorganic sediment.

Photographic Technique Group

An unconventional approach to habitat assessment (Greentree and Aldrich, 1976) used aerial photography to evaluate trout habitat in a northern California stream. Photo-interpretation tests showed a high correlation between actual habitat conditions and normal color photographs. Changes in vegetation were easily detected, but poor accuracy was obtained for depth estimation. Shade was evaluated by using shadow length measurements and solar formulas. Rubble, rocks, and gravel stream bottoms were identified in most instances at 1:1584 scale; fine and coarse rubble types were more easily identified at a 1:600 scale.

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Diverse Method Group

Seehorn (1970) designed a procedure for judging the relative quality of trout waters in National Forest streams in Georgia, Virginia, and South Carolina; it also appeared applicable to headwater bass streams in northern Georgia. Streams are given three grades for both present and potential conditions, with each grade given a score of 1 to 10. A biological grade is based on the stream's capacity to provide native trout fishing; a use grade is based on fishing pressure and actual use; and an overall grade is based on the first two grades.

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Recognizing that channel modification projects can result in environmental change, the U.S. Soil Conservation Service (1977) developed guidelines for the protection and enhancement of the stream environment. A biological index is obtained by rating various stream features (Table 3) on a scale from 1 to 10. Water chemistry and pollution are considered to be overriding limiting factors if severe enough to affect fish life. Sediment deposits are not rated since it is felt the rating of the pool/riffle ratios, width, acreage, and turbidity will reflect sediment effects. The scores are then multiplied by an importance factor to obtain individual stream feature scores. The scores are summed and divided by the total of the importance factor to obtain a final grade of 1 to 10. A grade of five or less indicates a stream with a low biological value. A use rating, a judgment based on fishing and related factors, is obtained by considering fish resources, access, ownership, fishing pressure and success.

A technique being developed by O. Fajen, Missouri Department of Fish and Game, Columbia, Missouri (pers. comm.) also rates a series of stream features on a scale of 1 to 10 (Table 3). Scores obtained for these features are not totaled in the belief that it is more useful to concentrate on those which indicate specific problems. The evaluated factors are intended to be free of subjective judgment and to take into account the deviation which might be expected in a particular stream. For instance, the stream bed condition factor emphasizes the stability of material and thus is as applicable to a sand/silt bottom stream as one dominated by gravel and boulders.

Sternberg (1978) developed methodology to provide necessary information for the determination of the best fishery management procedures in all types of Minnesota streams. A standard comprehensive format is used even though some of the information may not apply in all cases. Surveys are designed for use in two phases. A Phase I survey consists of walking or boating the entire stream and recording pertinent data. A Phase II survey consists of collecting

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detailed information on location and flow characteristics, watershed description and use, and general information on physical, biological, and fishery characteristics (Table 3). An additional form is provided for a summary of the stream survey and is divided into data pertaining to the entire stream and data representative of each similar reach. The stream is also classified according to the fish species for which it is best suited.

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Incremental Flow Group

Some methods orientated toward various relationships between a selected species and its environment are based on instream flow. Waters (1976) stressed the need of stream resource managers to determine the relationship between flow and various fish habitat parameters to evaluate the effects of present or proposed projects. He described a technique using transect measurements and a computer to express the relationship between streamflow and trout feeding, spawning, resting and cover areas. Stalnaker and Arnette (1976) intensively reviewed methods for determining instream flow needs for fish and other aquatic life and stressed the need for more research on target fish species at all life stages, refinement of large river measuring techniques and research on which all life stages are most vulnerable to flow fluctuations.

Most development and refinement of instream flow methodologies as related to impact assessment came after the formation of the Cooperative Instream Flow Service Group, a cooperative venture of the U.S. Fish and Wildlife Service and other governmental agencies. Hayden (1978) reviewed the background of the group and provided an overview of their activities. The Instream Flow Group incremental methodology has been applied or will be used on a large number of streams across the country (Coop. Instream Flow Ser. Group, 1979b) and has been described in detail by Stalnaker (1978, 1979a, 1979b).

The incremental flow method is intended to be used as a decision making tool and is designed to demonstrate the impact of any given flow regime on fish habitat potential. Basically it consists of a number of steps: 1) measurement of stream transects for velocity, depth, substrate, temperature, dissolved oxygen, and fish standing crop; 2) hydraulic simulation of desired stream reaches; 3) application of habitat evaluation criteria for each species or life stage of interest; and 4) calculation of a weighted usable area by life stage of each species for each desired flow or channel condition.

Several computer programs are used which can predict depth, velocity, width, and stage for different discharges. A stream reach simulation is used based on transects divided into subsections; each subsection is treated essentially as a channel with mean depth and velocity calculated for all desired discharges. The simulation takes the form of a multidimensional matrix of the calculated surface area of a stream having different combinations of depth, velocity, substrate, and cover.

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A composite probability of use can be determined from individual probability of curves as part of the application of habitat criteria for each life

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stage on species of interest, for instance, the composite probability between depth and velocity or between depth, velocity, and substrate. The weighted usable area (WUA) is a habitat index defined as the total surface area with a certain combination of hydraulic conditions multiplied by the composite use for the combined condition. The WUA roughly equates marginal habitat area to an equivalent area of preferred habitat. Habitat-discharge relationships can be plotted to assist in identifying critical time periods and limiting habitat availability for given life stages or species.

A recent expansion of the incremental flow methodology has incorporated cover into the model as a flow-related variable (Coop. Instream Flow Service Group, 1979a, 1980). Both overhead and instream cover are recognized. The construction and application of probability use curves have been explained by Bovee and Cochnauer (1977).

Habitat Evaluation Procedures (HEP) Group

Another type of target species method is based upon the formation of a quantitative index value for assessing habitat conditions. The U.S. Fish and Wildlife Service, primarily the Western Energy and Land Use Team at Ft. Collins, Colorado, has been developing a set of Habitat Evaluation Procedures (HEP) for about the past five years in response to the need for standardized quantitative methods (Raleigh, 1978).

Sparrowe and Sparrowe (1978) and Harker et al. (1980) traced the development of concepts that went into the formation of the HEP procedures through early rating systems (Hamor, 1970; Daniel and Lamaire, 1974), utilization of computer technology (Whitaker and McCuen, 1976) and the development of line charts graphically representing and rating wildlife characteristics (Whitaker et al., 1976). The "Missouri System" of terrestrial habitat assessment (Daniel and Lamaire, 1974) was modified into the Ecological Planning and Evaluation Procedures (Hickman, 1974 cited in Harker et al. 1980). These procedures were further refined into HEP Form 3-1101 (USFWS, 1976). These early procedures which are still in use in many areas were designed to provide a uniform nationwide method for determining impacts on fish and wildlife from water development projects. In practice, ten representative species that depend to some degree on the habitat under evaluation are selected at each sample site. The capability of the habitat to meet the requirements of these species is rated on a scale of 1 to 10 for each species. The sample site values for each habitat type are averaged to obtain a habitat type unit value. This unit value can be multiplied by the area of a particular habitat to obtain the number of habitat units for each habitat type. Project impacts can be analyzed by comparing "with" and "without" conditions of a particular project.

Sparrowe and Sparrowe (1978) reviewed the use of the Form 3-1101 HEP in wildlife habitat evaluation and cited the development of a prototype handbook by Flood et al. in 1977 ("A Handbook for Habitat Evaluation Procedures" USFWS Res. Pub. 132) containing a measurable, standard set of habitat characteristics to be used in evaluations.

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Raleigh (1978) and Schamberger and Farmer (1978) discussed further modifications and refinements of the HEP leading to the development of a habitat suitability index (HSI). Habitat parameters significant in the distribution and abundance of fish within an ecoregion are scored by the use of response curves constructed by life stage. The response curves illustrate the relationship between a suitability index and a habitat parameter. Selected habitat parameters are then measured in the field and compared with habitat requirements as indicated by the response curves. The HSI can then be obtained by combining suitability indices for all evaluated species. Multiplication of the HSI by the total area results in a habitat unit (HU) score which can be used in computing habitat losses or comparisons.

Draft guidelines for determining HSI values for cutthroat trout (USFWS, Western Energy and Land Use Team, Ft. Collins, Colorado, pers. comm.) illustrate the type and range of habitat parameters which can be employed. Physical habitat and life stage parameters are rated on a scale of 0.0 to 1.0 based on the degree to which the parameter meets the habitat requirements of the fish in question (Table 3). Habitat suitability stream and lake models are available from the Western Energy and Land Use Team for over 20 species of fish (rainbow trout and warm water species) from the South Atlantic, Great Lakes, and Texas-Gulf areas. A number of reservoir models are available for four USFWS regions. Models are also available for a large variety of mammals, birds, waterfowl, and including some for amphibians and turtles.

Revisions in the HEP have resulted in several recent publications. These discuss the justification for habitat based technique and the conceptual approach to habitat assessment (USFWS, 1980a), refine the HEP procedure and discuss how the conceptual approach can be implemented (USFWS, 1980b), provide guidelines for the development of habitat suitability index models (USFWS, 1981) and describe the means for determining the extent of human uses of wildlife and the dollar value of their uses (USFWS, 1980c). The new Habitat Evaluation Procedures 102 ESM (USFWS, 1980b) emphasize two major changes in methodology since the 1976 HEP version (USFWS, 1976). These are determining HSI values using documented models and the analysis of individual evaluation species rather than habitat types. Selection of these species can be approached in two ways, selection of those with a high public interest or economic value, or selection of those that will provide a broader ecological perspective of the area. Project goals will determine the choice. Aquatic handbooks are presently being developed for a number of aquatic ecoregions and will supplement HEP procedures by presenting regional habitat requirements for selected species.

The new HEP (USFWS, 1980b) are detailed and include discussion and guidelines to the following subjects: applicability of HEP, cost estimation, defining the study area, selecting evaluation species, calculating total habitat area, calculation of habitat suitability index, using habitat units in habitat assessment, trade-off analyses, compensation analyses, and sampling.

NON-SALMONID STREAM METHODS

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Two procedures are used in Kansas for non-salmonid stream project impact evaluation. The first method (U.S. Soil Conservation Service, 1978) rates

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various physical, chemical, and biological attributes of the habitat on a score of 1 to 10. The average values obtained for each of these three groups are used to compute an average habitat value which can also be converted into habitat units. Biological features were based upon the presence of both fish and macroinvertebrates (Table 3). Three evaluations are conducted to fully demonstrate the impact of watershed projects: present, future (15 yr) with the proposed project, and future without the proposed project.

The second method (K. Brunson, Kansas Dept. of Fish and Game, Pratt, Kansas, pers. comm.) designed originally to evaluate Kansas Department of Transportion bridge projects uses a somewhat similar rating scheme. Various physical, chemical, and biological habitat features (Table 3) are rated from 0 to 1 or 0 to 5. Total group scores are summed to obtain a total habitat score. This method is undergoing revision and is a good example of simple procedures that can be used when there are few resources available for extended surveys (K. Brunson, pers. comm.).

SUPPLEMENTAL METHODS

These methods emphasize or concentrate on only a part of the habitat, i.e., substrate, and might be appropriate as part of a broader survey or which, with more development, may have greater application in the understanding of the relationships between aquatic stream habitat and watershed activities.

Substrate Score correlates highly with geometric mean particle size and fish production and has good potential for assessing the quality of salmonid spawning and rearing habitat (Crouse et al. 1981). In this technique the size of the first and second dominant materials, the degree of embeddedness of the largest material, and the size of the embedding material are assigned numbers depending upon their in-category rank. The sum of the scores for the four categories represent an index directly related to suitability for aquatic life. Lower scores represent poor habitat suitability for benthic invertebrates and vice versa. Lotspeich (1978) emphasized the rapidity of the Substrate Score technique and suggested adding observations of grain shape and grain roundness.

Two other streambed evaluation techniques helpful to biologists in evaluating the biological significance of the physical environment were also described by Lotspeich (1978). The first technique involves constructing a size-percent accumulation graph from stream gravels dry sieved according the the Udden-Wentworth scale to determine median grain size and a sorting coefficient. The resultant curves allow biologically significant inferences to be drawn about the substrate and the stream's nature. For instance, although a sediment at one location might be coarser than at another, it still may not be a desirable habitat for fish or macroinvertebrates because of small pores and low permeability due to poor sorting. While potential productivity appears to increase as grain size increases with good sorting, it is not necessarily true that the coarser a sediment the higher its productivity.

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The second technique estimates the efficiency with which a gravel substrate sample yields water by gravity flow. Gravels yielding a large amount of water in a short time have a high pore space efficiency, implying large pores, minimal fine grains and high permeability. Such sediments would be representative of an environment allowing sufficient space for movement, reareation, and waste removal.

Shirazi et al. (1979) proposed two measures in a monitoring program to assess the possible impact of silvicultural activities on salmonid spawning habitat: the geometric mean diameter (dg) of the spawning gravel and the total area of spawning gravel in a given reach. The dg has been recommended as a standard measure for substrate characterization in fisheries work by Platts et al. (1979) who found that it relates well to permeability, porosity, and embryo survival.

Salmonid habitat has been suggested as providing meaningful indications of watershed characteristics because of the capacity of the substrate to integrate many aspects of climate, vegetation, soil type, land form and human activities (Shirazi and Seim, 1979). An assessment of the quality and quantity of spawning gravels could be made using embryo survival estimates of 80% or more, 80-50%, 50-25%, and 25% or less to rate corresponding dg categories of > 15, 15.25 - 10.75 mm, 10.75 to 7.0 mm, and 7.0 mm.

Lotspeich and Everest (1981) proposed using the ratio of the geometric mean diameter and sorting coefficient as a measure of the quality of riffle gravels for salmonid reproduction. Preliminary relationships between index numbers and survival-to-emergence salmonid alevins indicate that the fredle index ($f_1 = dg/S_o$) is responsive to slight changes in gravel composition, survival, and variation in intragravel habitat requirements.

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SECTION 6

DISCUSSION

This review represents the status of assessment methodology at a point in time and will quickly become outdated as new methods develop and older ones are revised. It should be emphasized that the grouping of the reviewed methods as expressed here is but one way of examining them; other logical arrangements may become apparent with further additions and refinements to the methodology. It is difficult to classify the reviewed methods entirely on the basis of the type of parameters used (Table 3). The purpose for which a method was intended or the basic philosophy of its development seem to be more important in determining its place in some sort of classification scheme.

The methods were classified on the basis of stream type (salmonid, non-salmonid, or both combined) primarily to allow potential users to become aware of methodology currently used in their own area of interest. There is little upon which to differentiate these methods, however, based on the type of parameters examined (Table 3). In fact, a method used for non-salmonid habitat was developed for salmonid streams (USSCS, 1978). Some differences between these methods which do appear are: 1) less emphasis on surrounding area, riparian zone, stream banks, and fish-habitat related parameters in salmonid streams, 2) less emphasis on stream banks by combination methods than salmonid stream methods, and 3) less emphasis on chemical parameters by salmonid stream methods.

Validation is one of the most important aspects confronting management's decision on assessment technique selection. The difficulty of duplicating the results of subjective systems such as Daniel and Lamaire (1974) has been expressed by Whitaker et al. (1976). Whelan et al. (1979) emphasized the lack of comparative studies to determine if different methods provide similar results using the same data base. They evaluated three wildlife assessment techniques using deer, wild turkey, and squirrel data and obtained considerable variation in the results. Whelan et al. (1979) also believed that the system that incorporates the best available data and that is the least subjective should be the most accurate, but that the question of accuracy will not be resolved until enough systems have been compared and sufficient replicated validations made. While their investigations concerned wildlife assessment methods, their argument is no less valid for aquatic systems.

Cairns (1981) emphasized that the development of a predictive capacity and a means of validating the accuracy of predictions are most important in biological monitoring of aquatic ecosystems. Similarly, the ability to predict and validate the results of habitat alteration is also very important.

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The highly developed HEP (USFWS, 1980b), a system concerned with habitat potential is designed for all stream situations, but requires high levels of expertise both in the field and in data analysis and awaits the development of regional handbooks to become fully operational. It is also applicable only to selected species of interest. Schamberger (1979) emphasized that these procedures provide an objective and quantitative estimate of the value of fish and wildlife resources. Habitat quality and quantity are integrated into a single index value or habitat unit which can be used in comparisons between sites or ideal conditions.

Farmer (1978) believed that while the methods are not perfect, they provide an objective tool for assessing the effects of water resource development. Hickman and McMahon (1979) suggested they could be used for endangered species management by evaluating impacts of reservoir construction to endangered species management by evaluating impacts of reservoir construction to endangered fish habitat prior to impoundment and comparing the rating to predicted post impoundment results. Identification of impacted parameters could result in project modifications. The procedures would also be of help in selecting potential release sites for endangered species. Harker et al. (1980) considered these methods as the probable state-of-the-art in terms of their approach in developing criteria indicating the relationship between the proportions of different habitats and their relative contribution toward meeting species requirements.

Trial et al. (1980) found that while HEP was useful for planning and mitigation for large projects, they were less valuable for small or short-term projects. Trial and Stanley (1980) applied HEP using HSI values based on both physical measurements and the ratio of observed to maximum populations in the East Branch of Presque Isle Stream in Maine and found the values of little use in predicting populations if they were based on inadequate information.

Stalnaker (1979a) believed that there is evidence pointing to the validity and utility of the Instream Flow Group methodology on trout and salmon streams. Validation of this method was started on various types of streams in Wyoming, Iowa, and Oregon (Coop. Instream Flow Group, 1979b).

Many of the methods result in the development of an index value. Daniel and Lamaire (1974) have expressed the advantages of such values in providing a total resource rating and a basis for determining mitigation needs. The use of such a system also simplifies comparisons between stations, areas of different times.

A number of methods result in a rating of 1 to 10 or 0 to 1 (Seehorn, 1970; Eiserman et al., 1975; Soil Conservation Service, 1977, 1978). Others result in a Habitat Quality Index (HQI) (Binns and Eiserman, 1979), Weighted Usable Area (WUA) (Stalnaker, 1978, 1979a, 1979b), or Habitat Suitability Index (HSI) (USFWS, 1980a). Many of these values can be converted to habitat units, an area rating which can easily be used for comparative purposes. Dunham and Collotzi (1975) cautioned that while habitat ratings were appealing, they do not consider productivity levels, stream access, angling success and similar factors.

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The results of a survey by the author (40 state agencies, pers. comm.) indicate that very few state agencies have developed or used a habitat assessment technique specifically for non-point source pollution investigations, even though a majority of those queried did acknowledge the desirability of such techniques. The States of Oregon and Washington both use techniques based on channel stability (Pfankuch, 1975) with additional biotic variables (Rickert et al., 1978; Washington Dept. Ecology, pers. comm.). The State of Wisconsin uses a biotic index developed by Hilsenhoff (1977) for NPS investigations; this system, however, is not based on physical parameters. North Carolina (Lenat et al., 1979) uses a similar non-physical stream assessment system based on a modification of Hilsenhoff (1977). South Dakota (Glover, 1975) used the method of Herrington and Dunham (1967) to inventory trout habitats in watersheds affected by road and railroad construction, timber management, agricultural practices, mining, and flood control projects.

Methods are currently being revised within the Bureau of Land Management with the suggestion that it may be advantageous to use handbooks that would provide guidelines and options for information gathering, leaving the choice of the most suitable method up to the biologist. Discussions are also continuing between this agency, the U.S. Forest Service, and the Oregon Department of Fish and Wildlife concerning an agreement to use the same inventory procedures (N. Armantrout, USBLM, Portland, Oregon, pers. comm.).

Vannote et al. (1980) proposed that physical variables within a river system are present in a continuous gradient and that community structure and function adjust to changes in a number of geomorphic, physical, and biotic variables. Therefore, for an assessment technique to be effective for comparative purposes, it may be necessary to use it in stream reaches that are at the same level of response to these variables.

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